Saturating Riparian Buffers In Tile Drained Landscapes for Nitrate Removal

Dan B. Jaynes, USDA-ARS-National Laboratory for Agriculture and the Environment

and

Tom M. Isenhart, Iowa State University

Natural Resource Ecology and Management

USDA

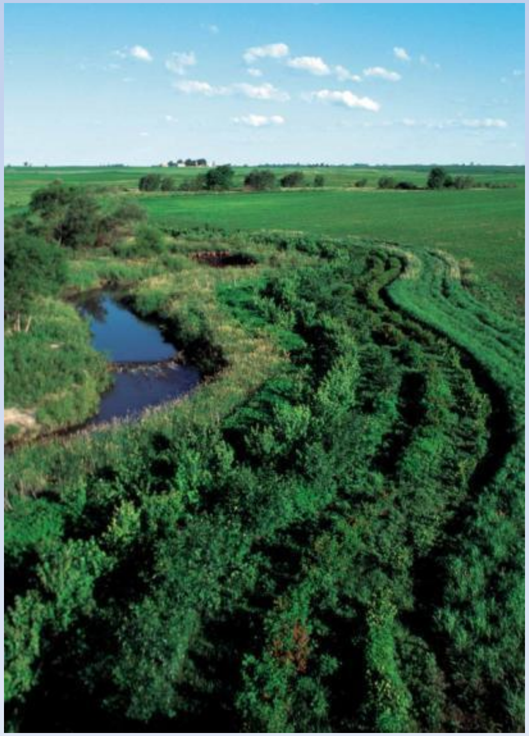
Natural Resource Ecology and Management

IOWA STATE UNIVERSITY

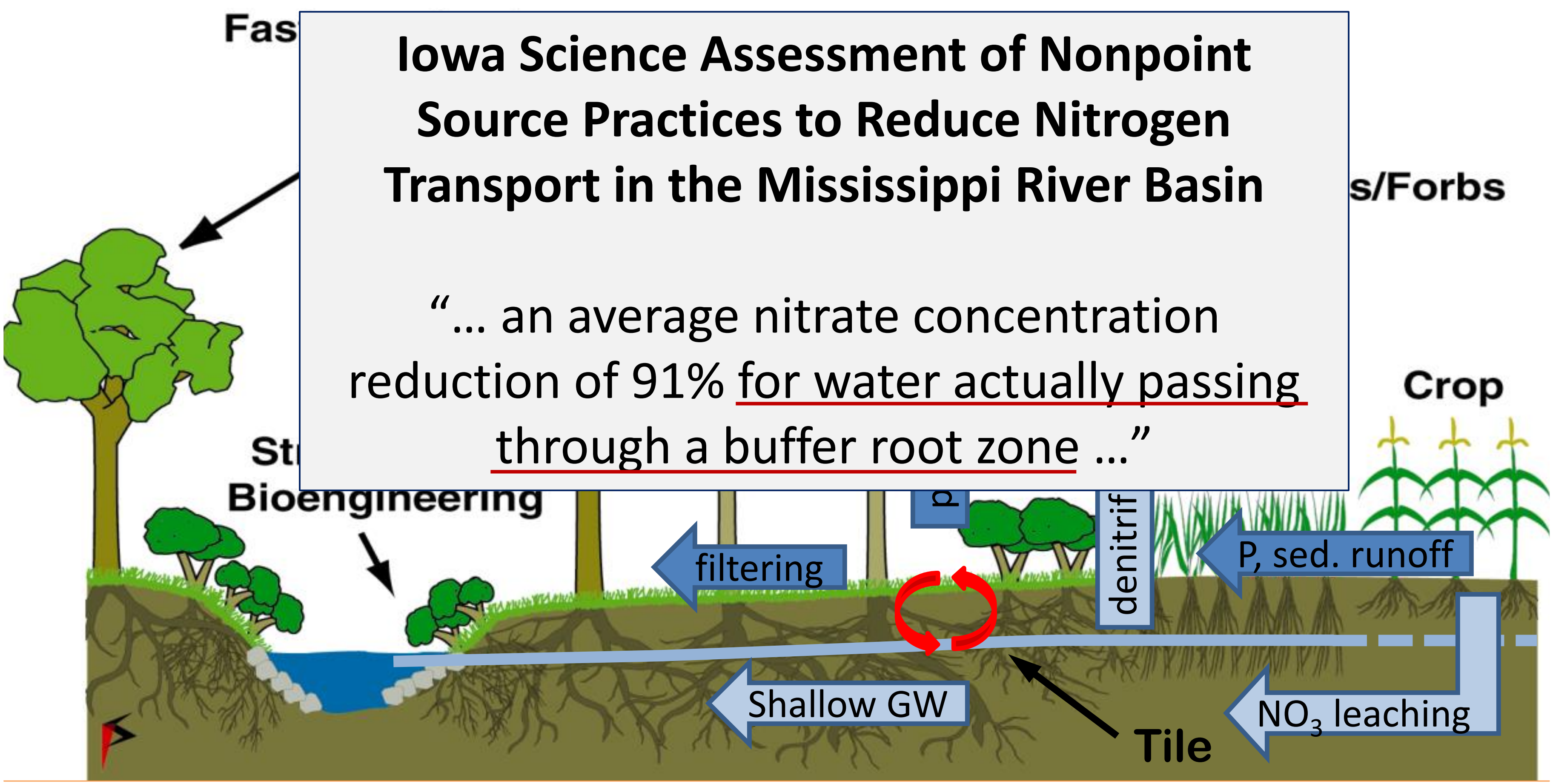
College of Agriculture and Life Sciences

LEOPOLD CENTER



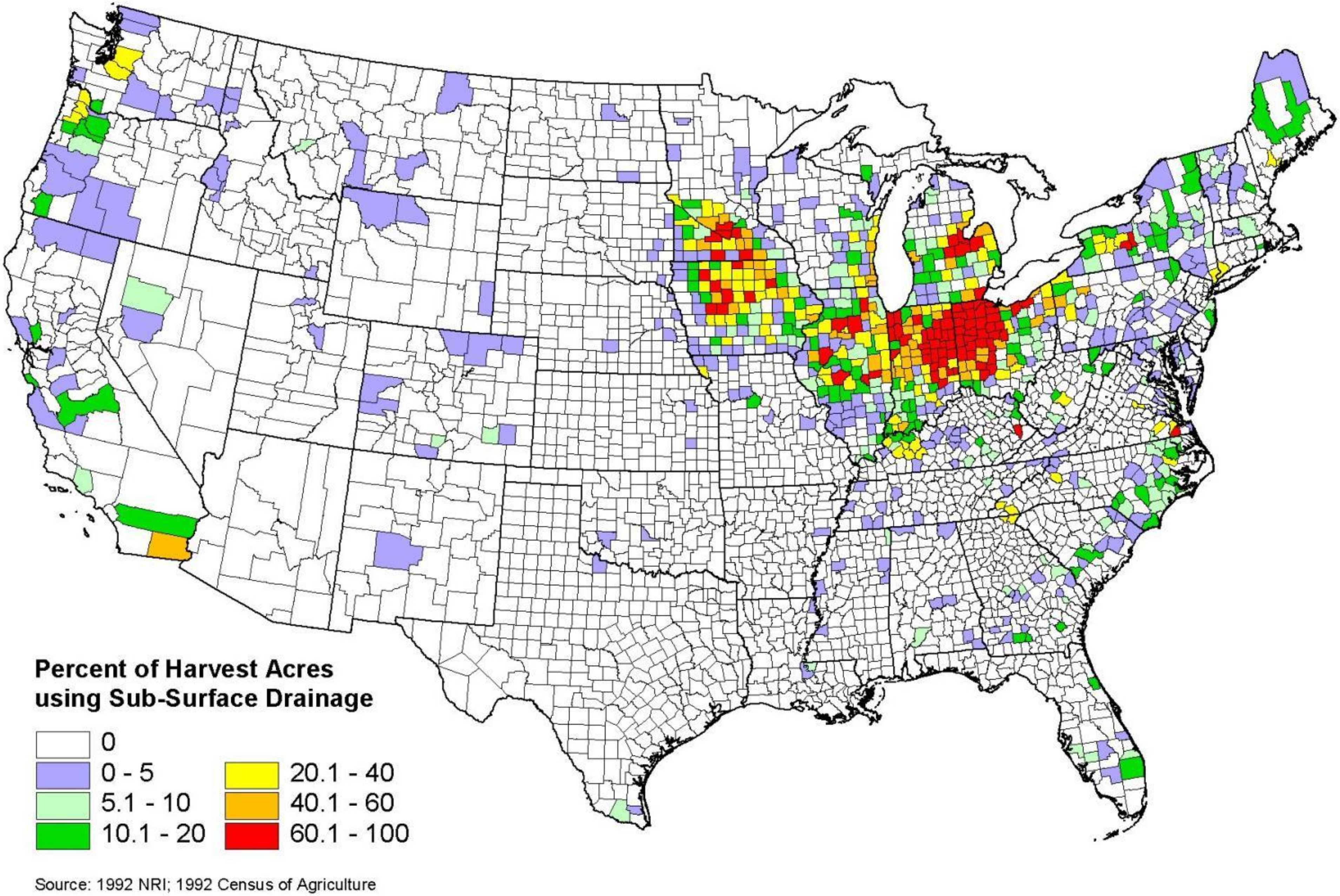



Schematic of nutrient retention in a riparian buffer.



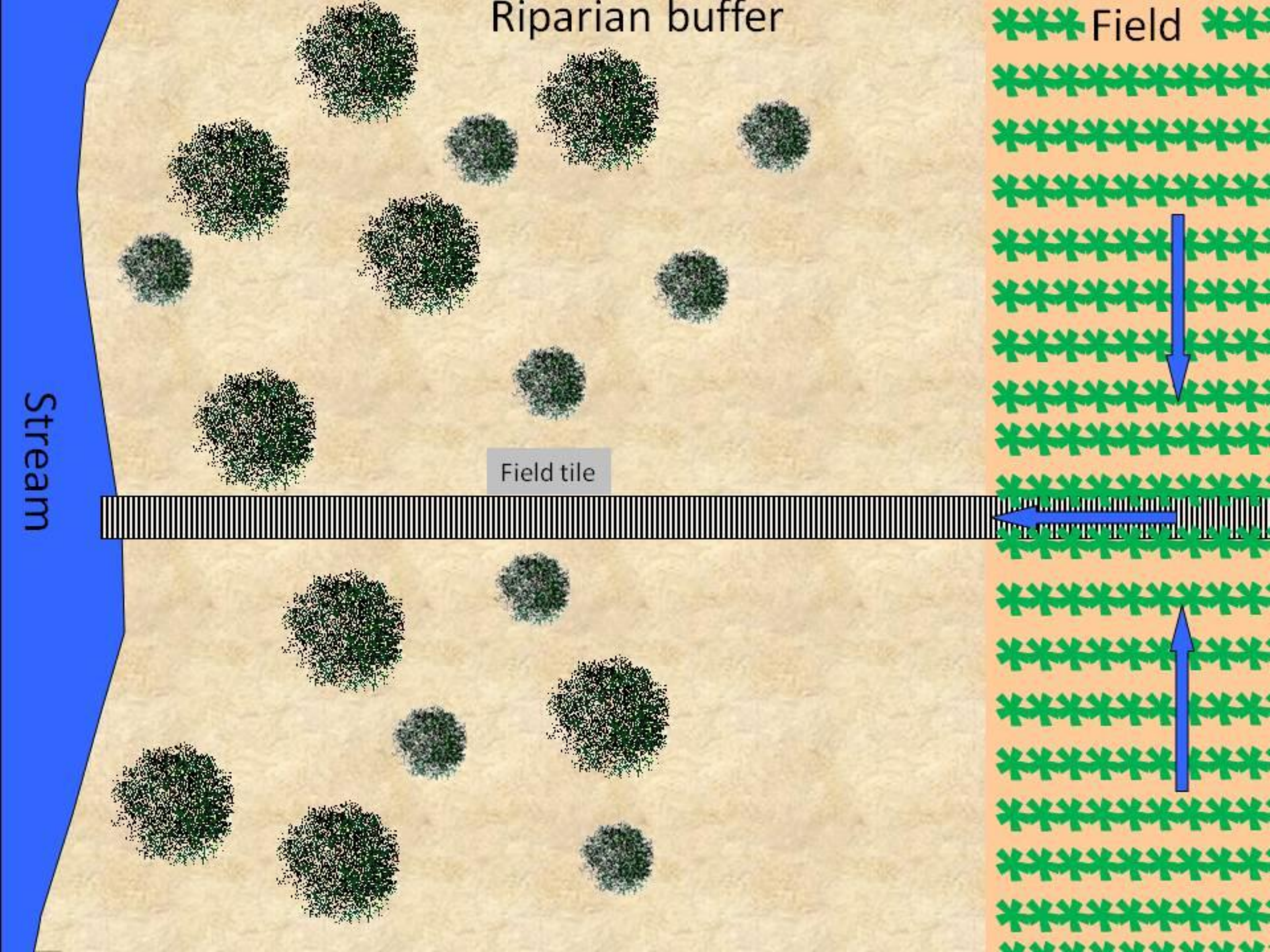
Iowa Science Assessment of Nonpoint Source Practices to Reduce Nitrogen Transport in the Mississippi River Basin

"… an average nitrate concentration reduction of 91% for water actually passing through a buffer root zone …"

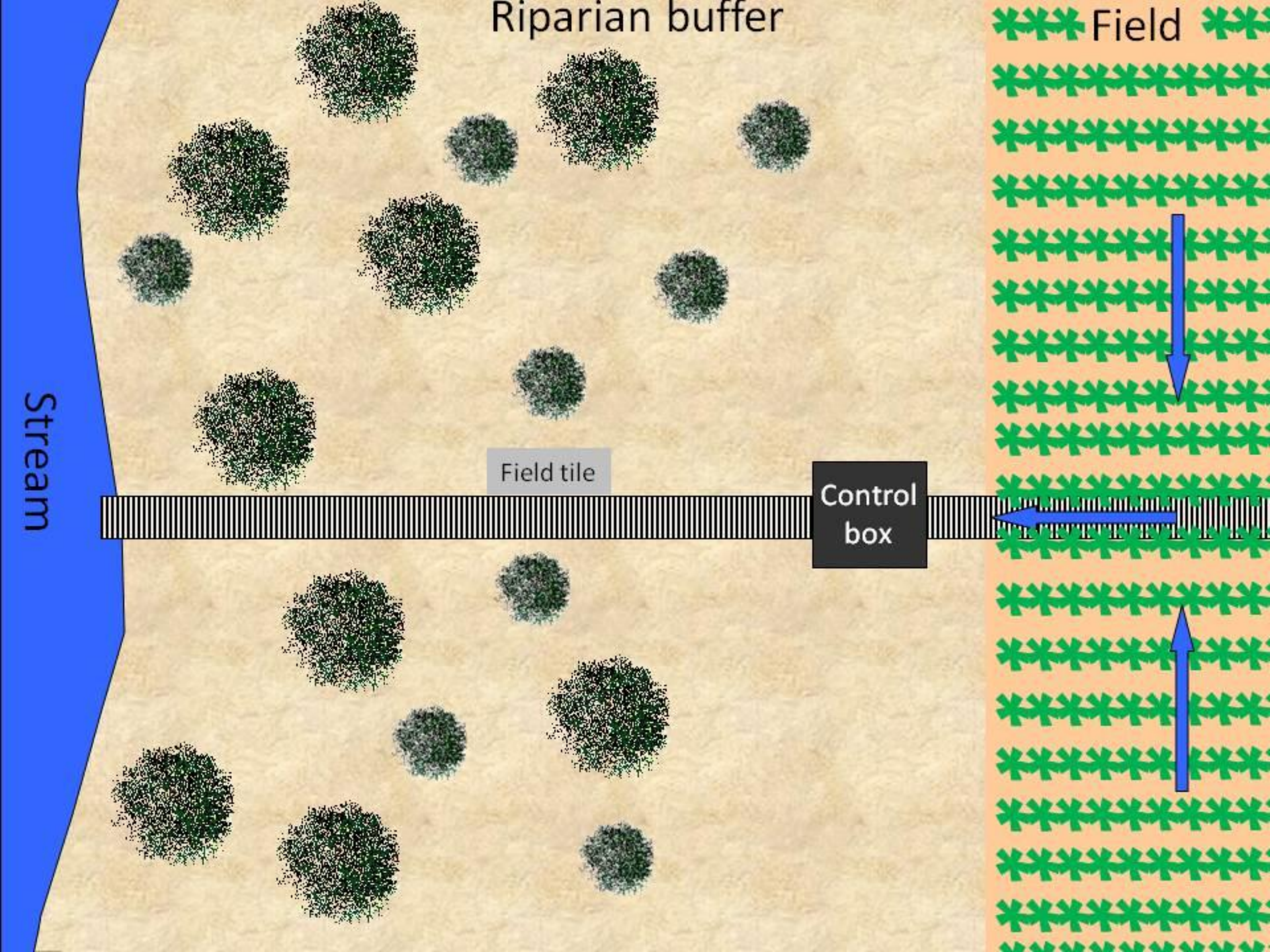

Percent of Harvest Acres
using Sub-Surface Drainage
0
0 - 5
5.1 - 10
10.1 - 20
20.1 - 40
40.1 - 60
60.1 - 100
Source: 1992 NRI; 1992 Census of Agriculture

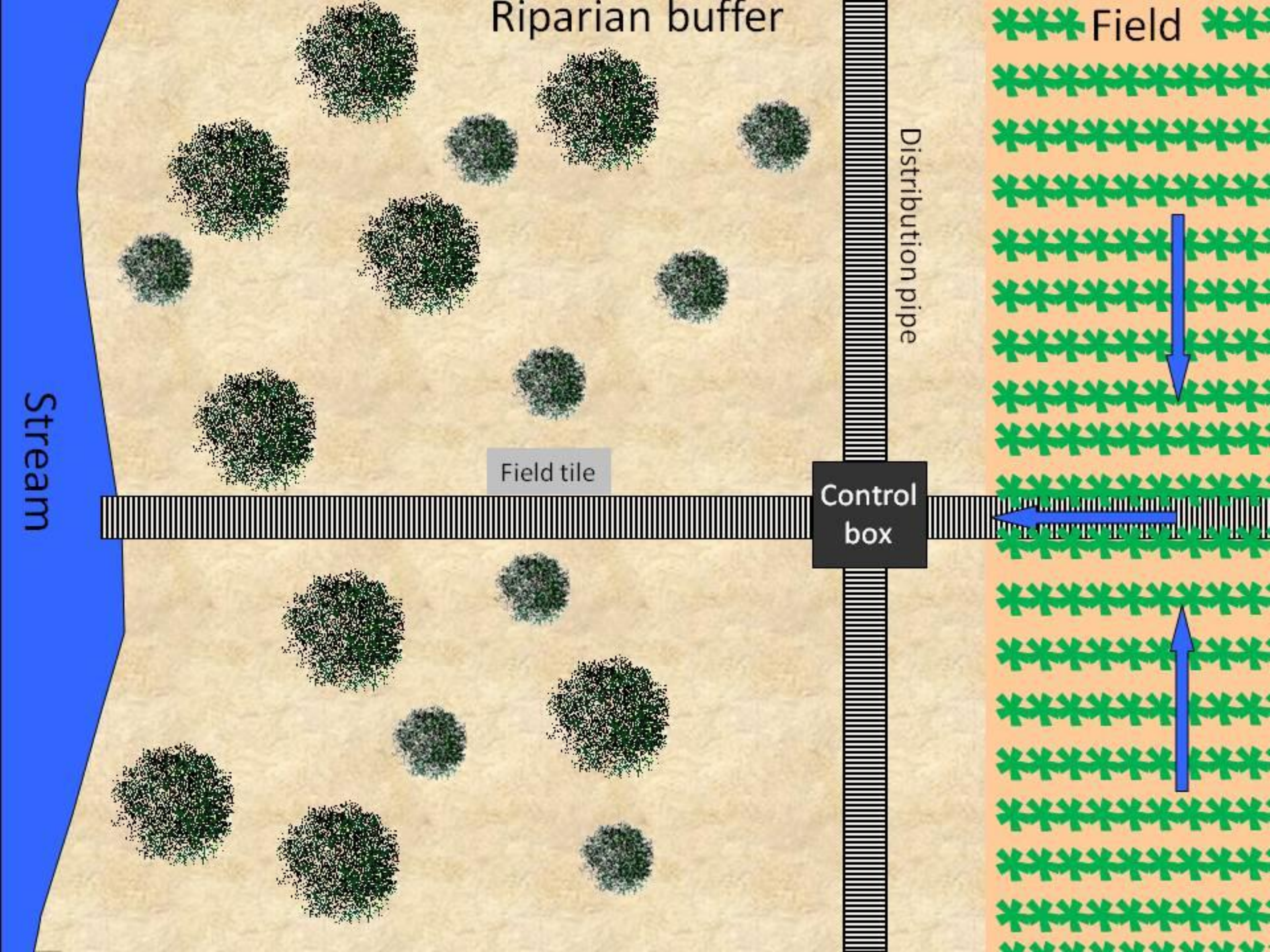
Question:

- Could reconnecting tile flow to riparian buffers remove substantial amounts of nitrate before it reaches surface waters?

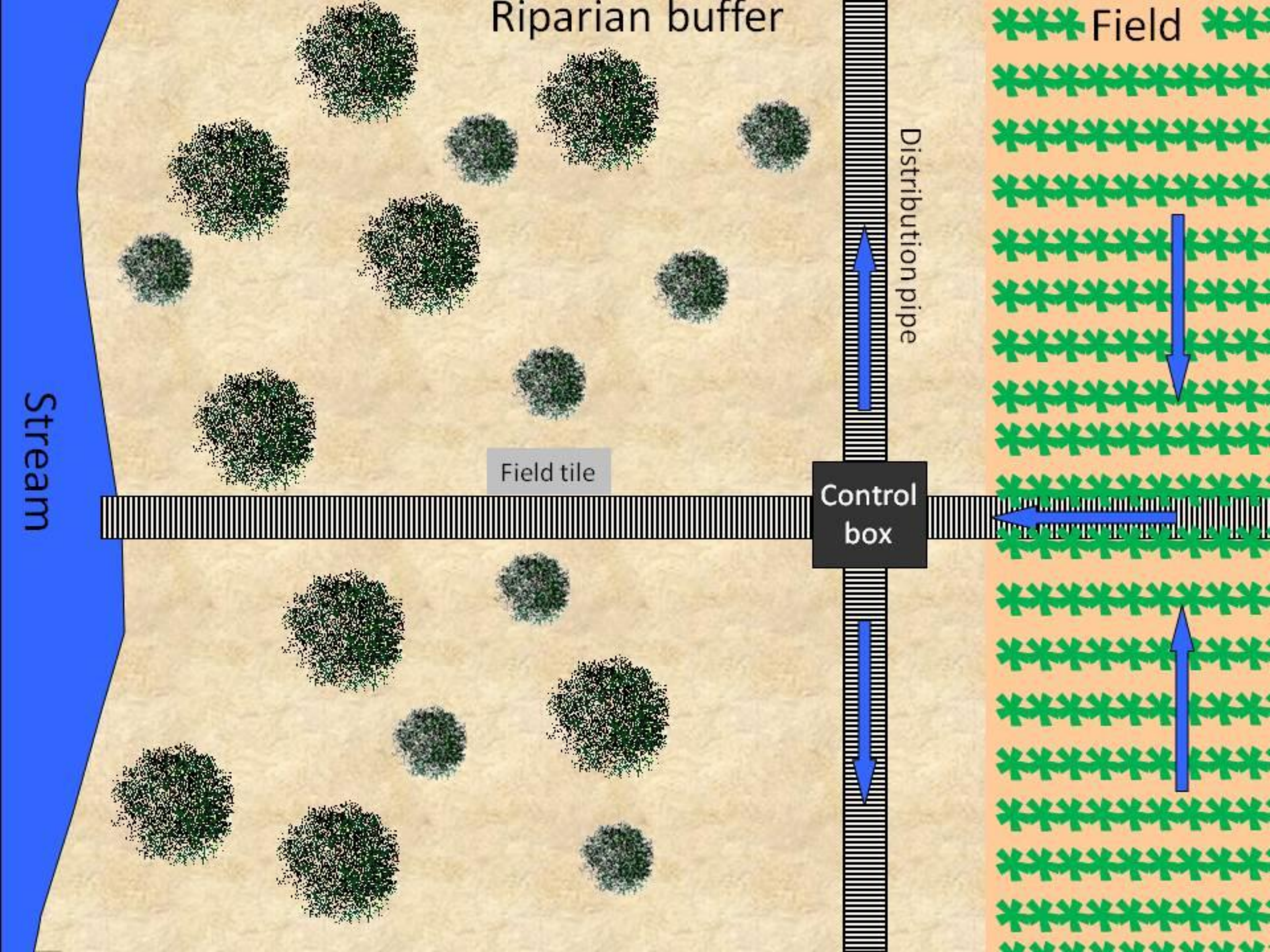


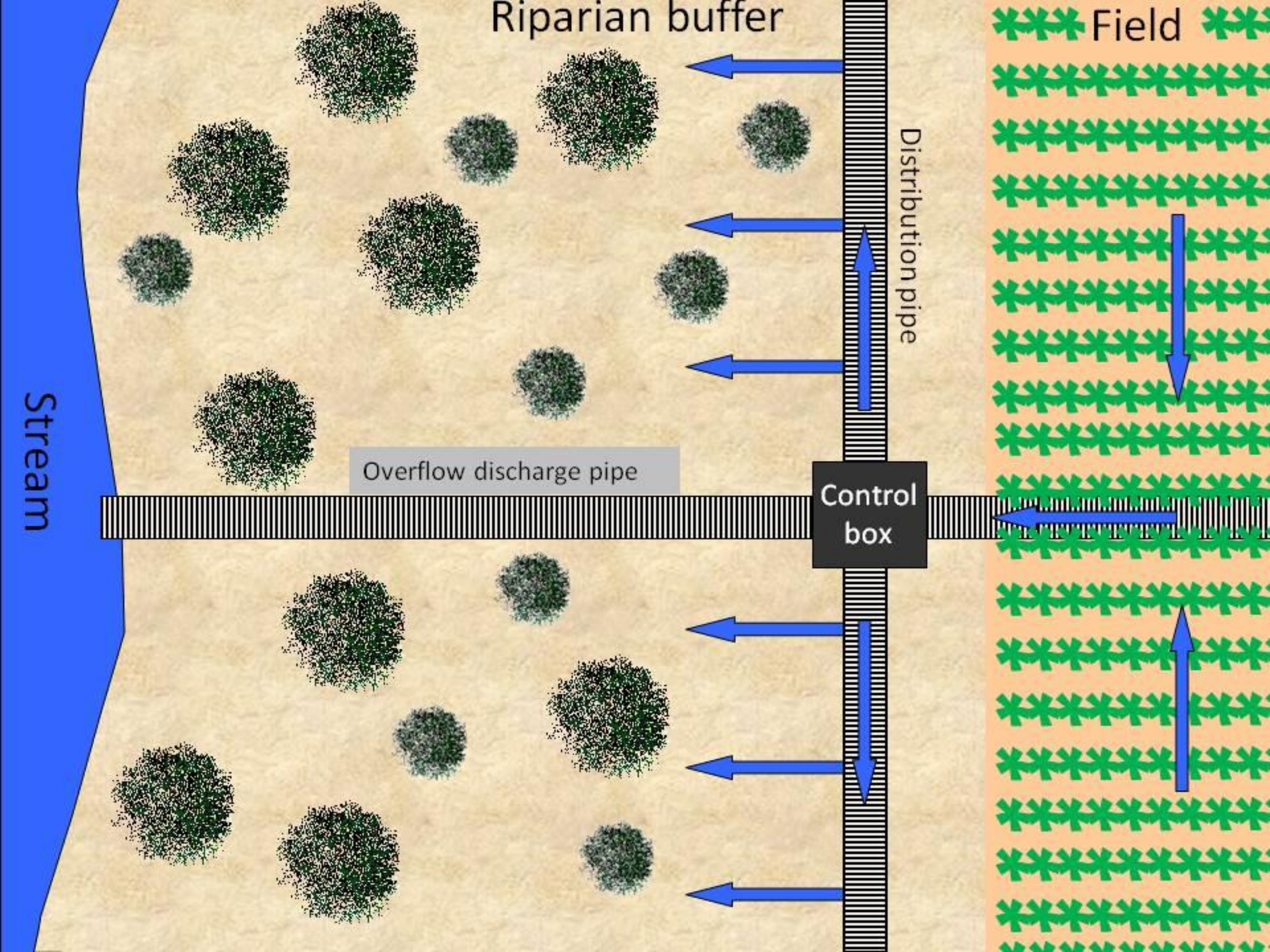
Riparian buffer
Field
Stream
Field tile


Riparian buffer
Field
Stream
Field tile
Control box

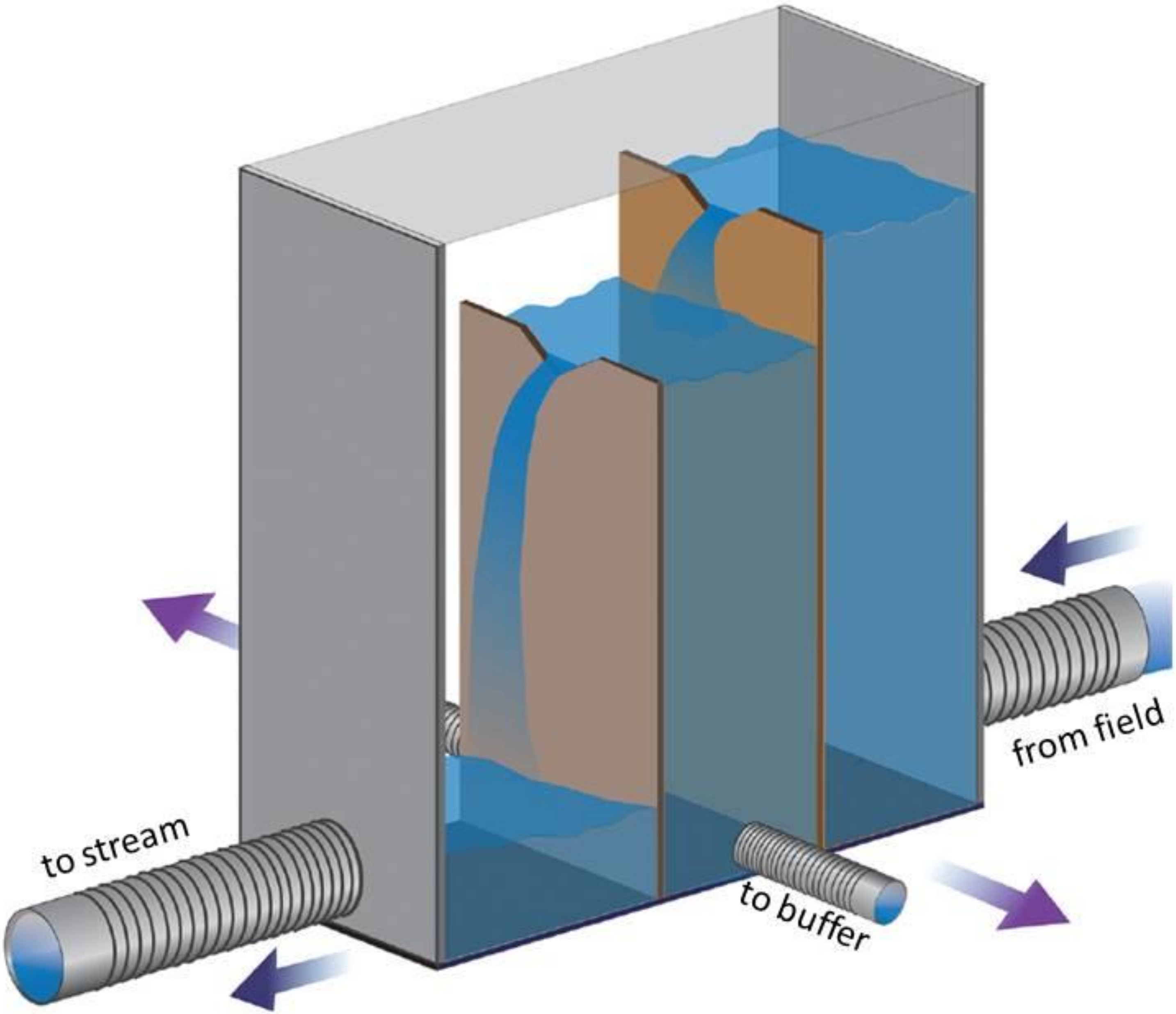


Riparian buffer
Field
Distribution pipe
Stream
Field tile
Control box


Riparian buffer
Field
Distribution pipe
Stream
Field tile
Control box

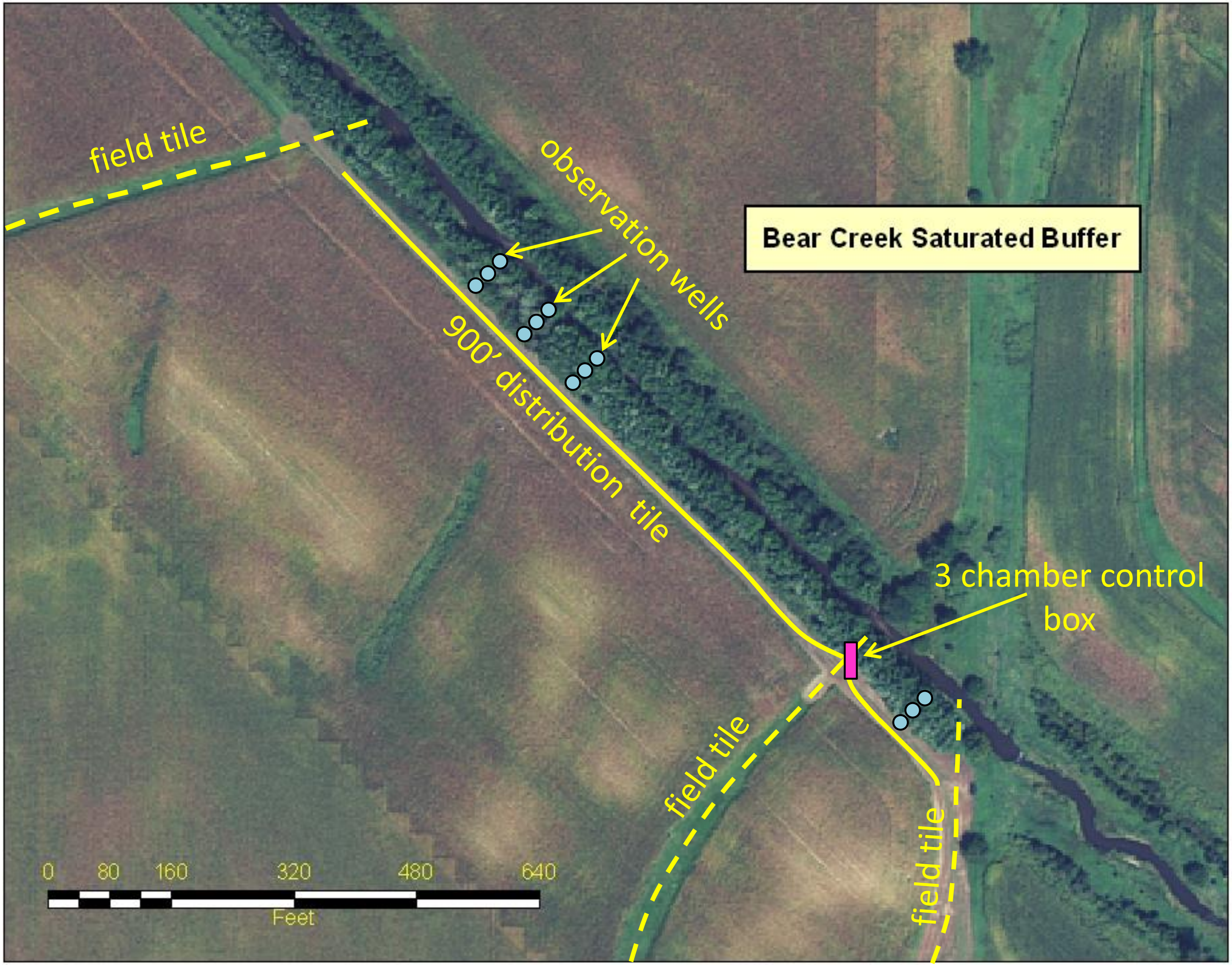


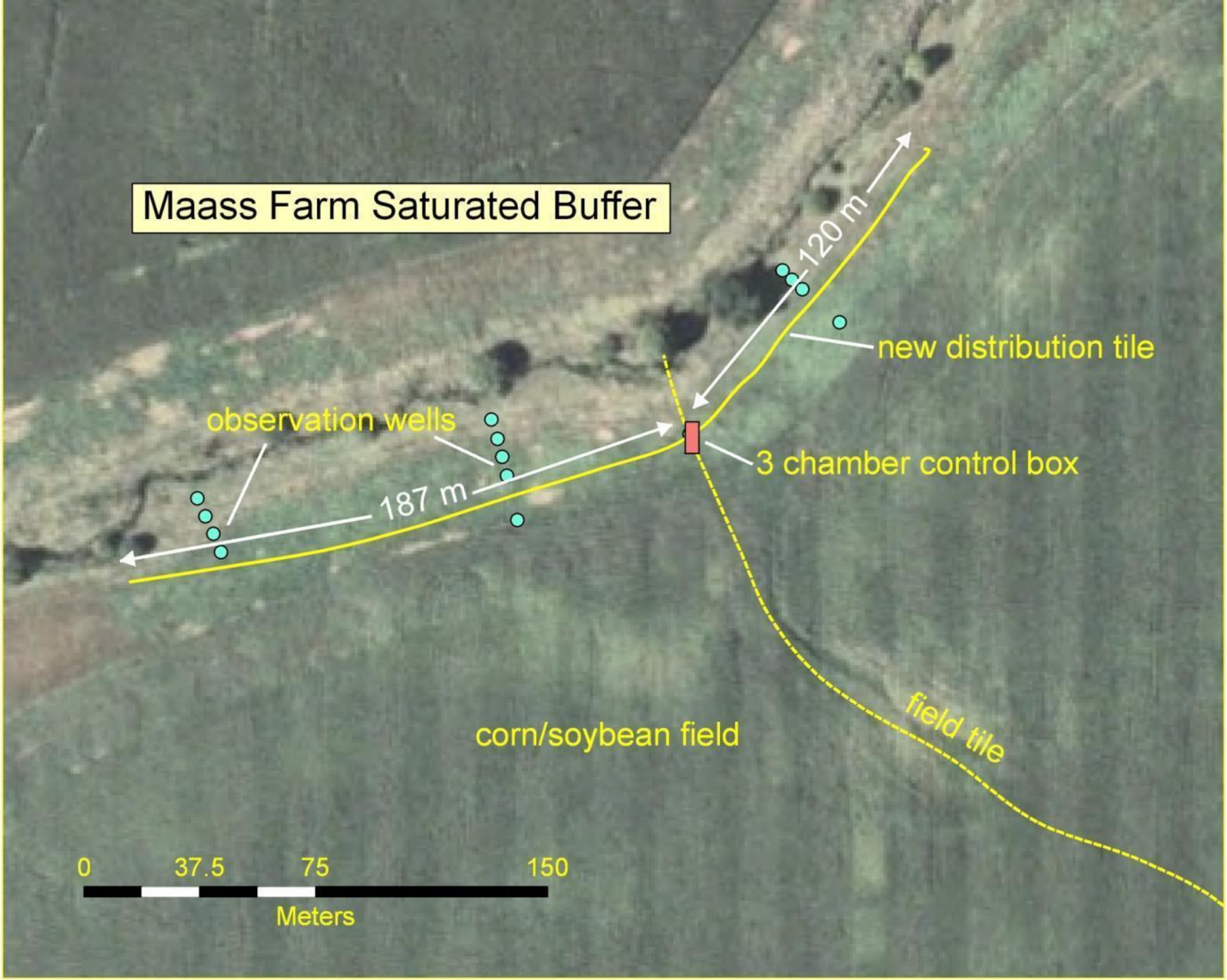
Riparian buffer
Field
Distribution pipe
Stream
Overflow discharge pipe
Control box



to stream
to buffer
from field

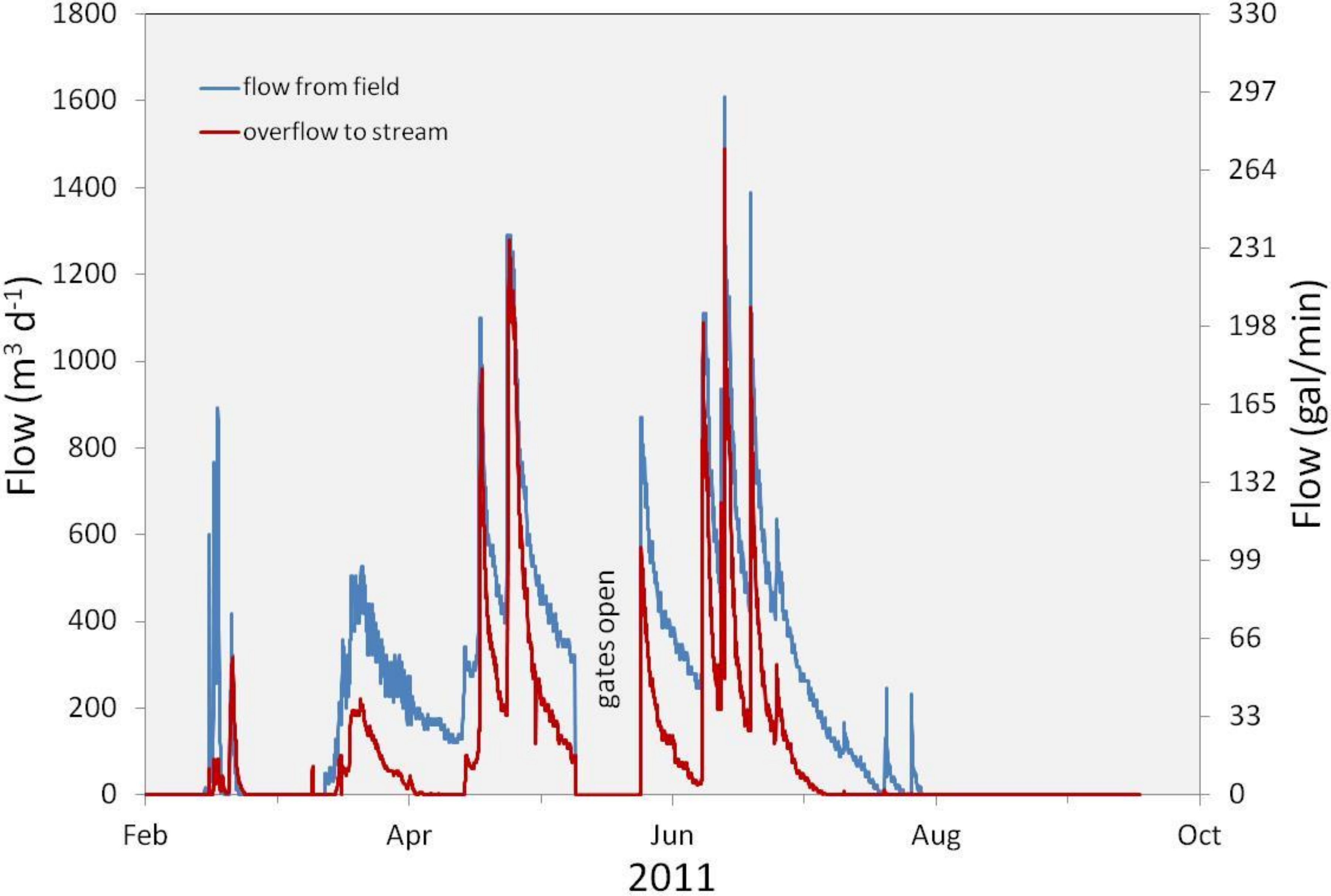

Does it work?


Bear Creek Saturated Buffer
field tile
observation wells
900' distribution tile
3 chamber control box
field tile
field tile
0
80
160
320
480
640
Feet

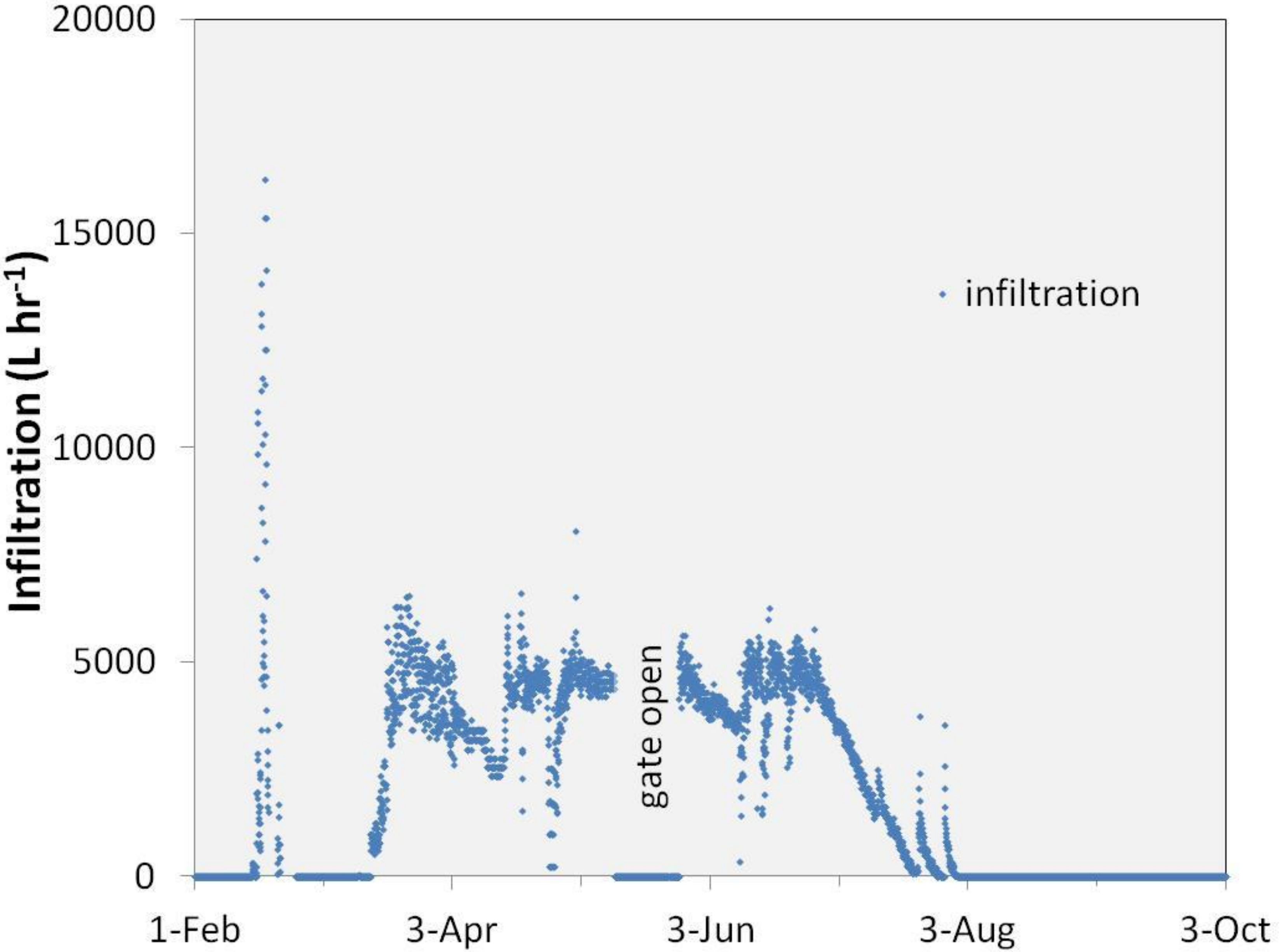

Maass Farm Saturated Buffer
120 m
new distribution tile
observation wells
3 chamber control box
187 m
corn/soybean field
field tile
0
37.5
75
150
Meters

Results for Bear Creek site

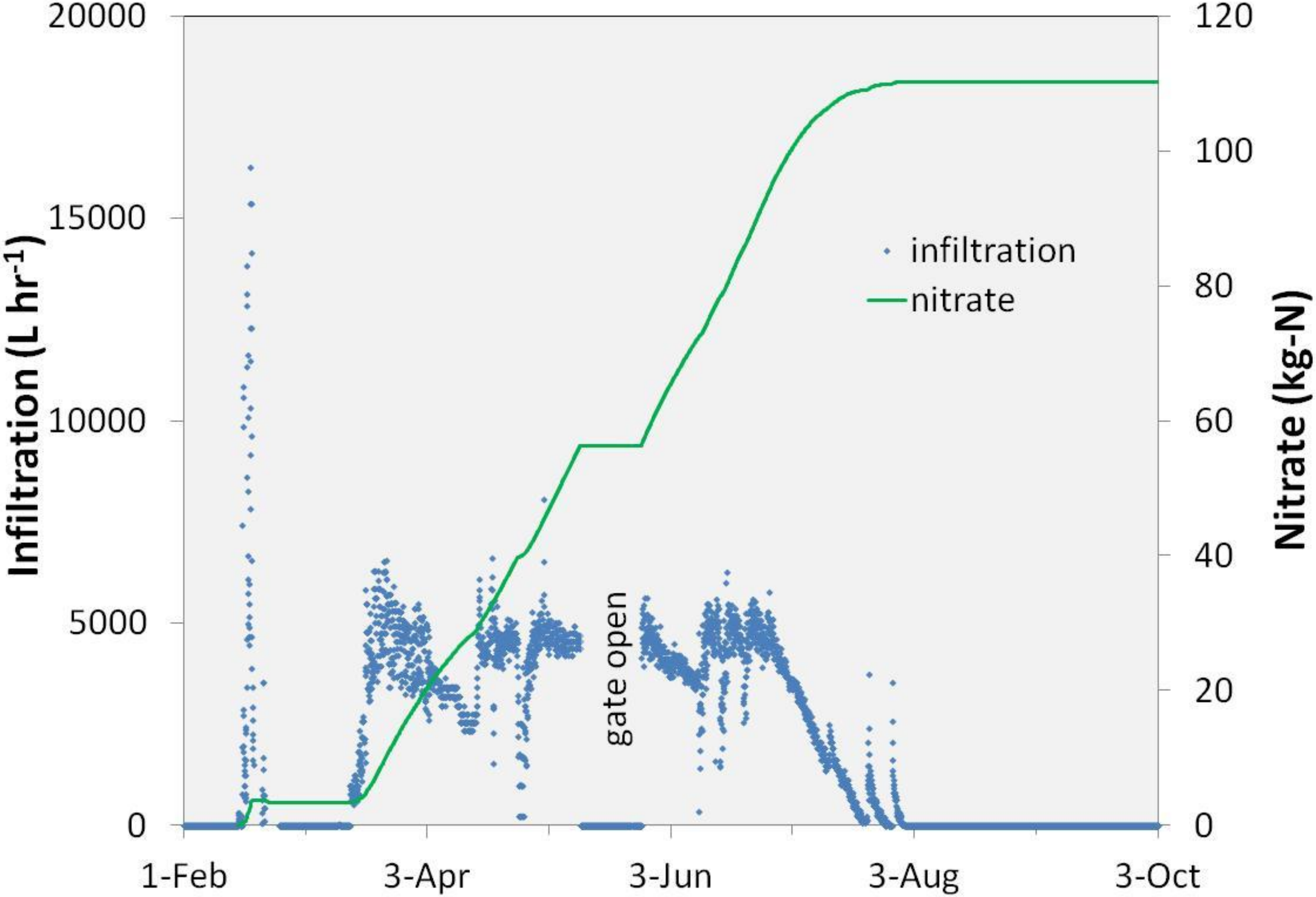
Flow measurement



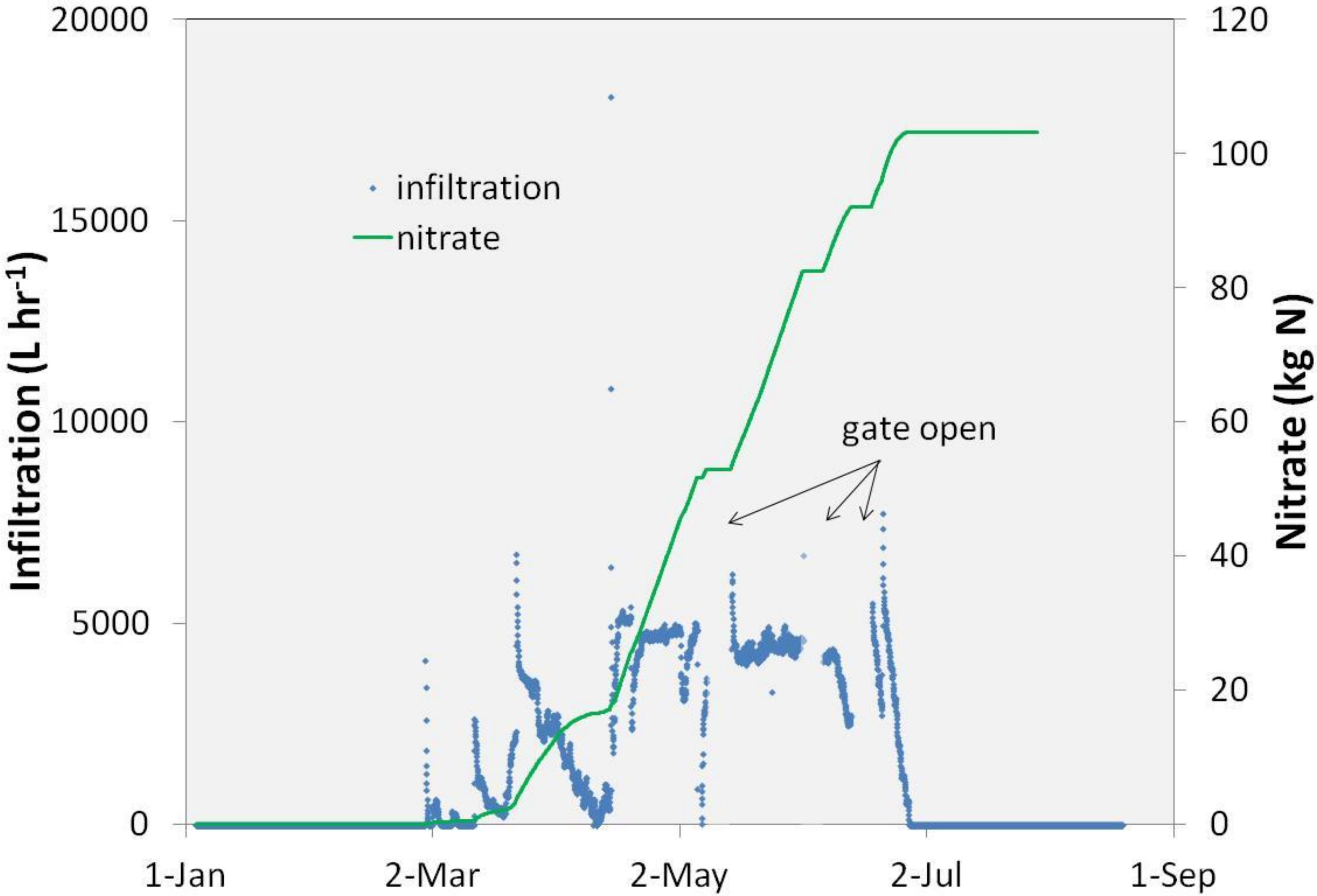
Water and cumulative nitrate diverted through buffer in 2011

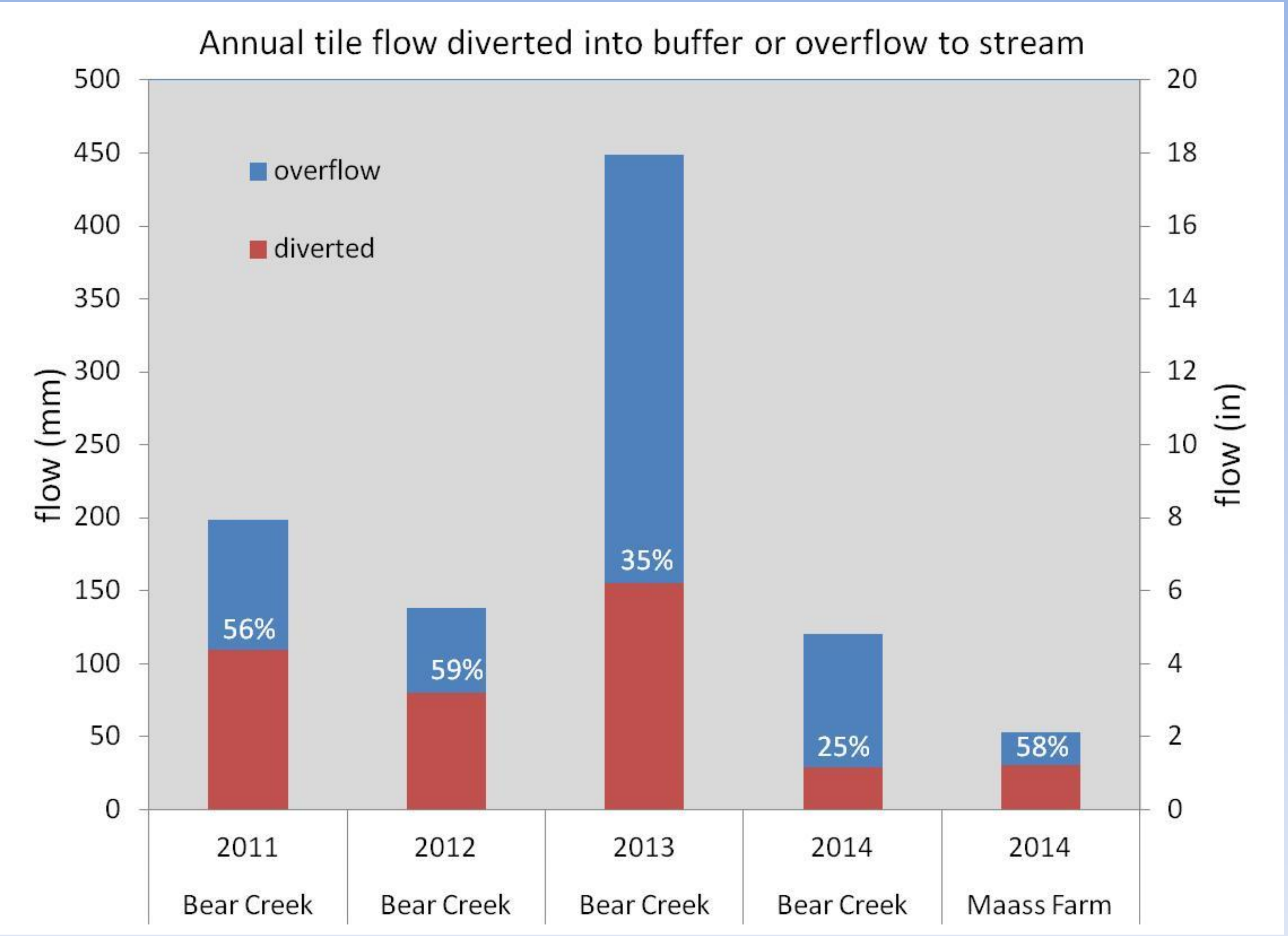


Water and cumulative nitrate diverted through buffer in 2011



Water and cumulative nitrate diverted through buffer in 2012

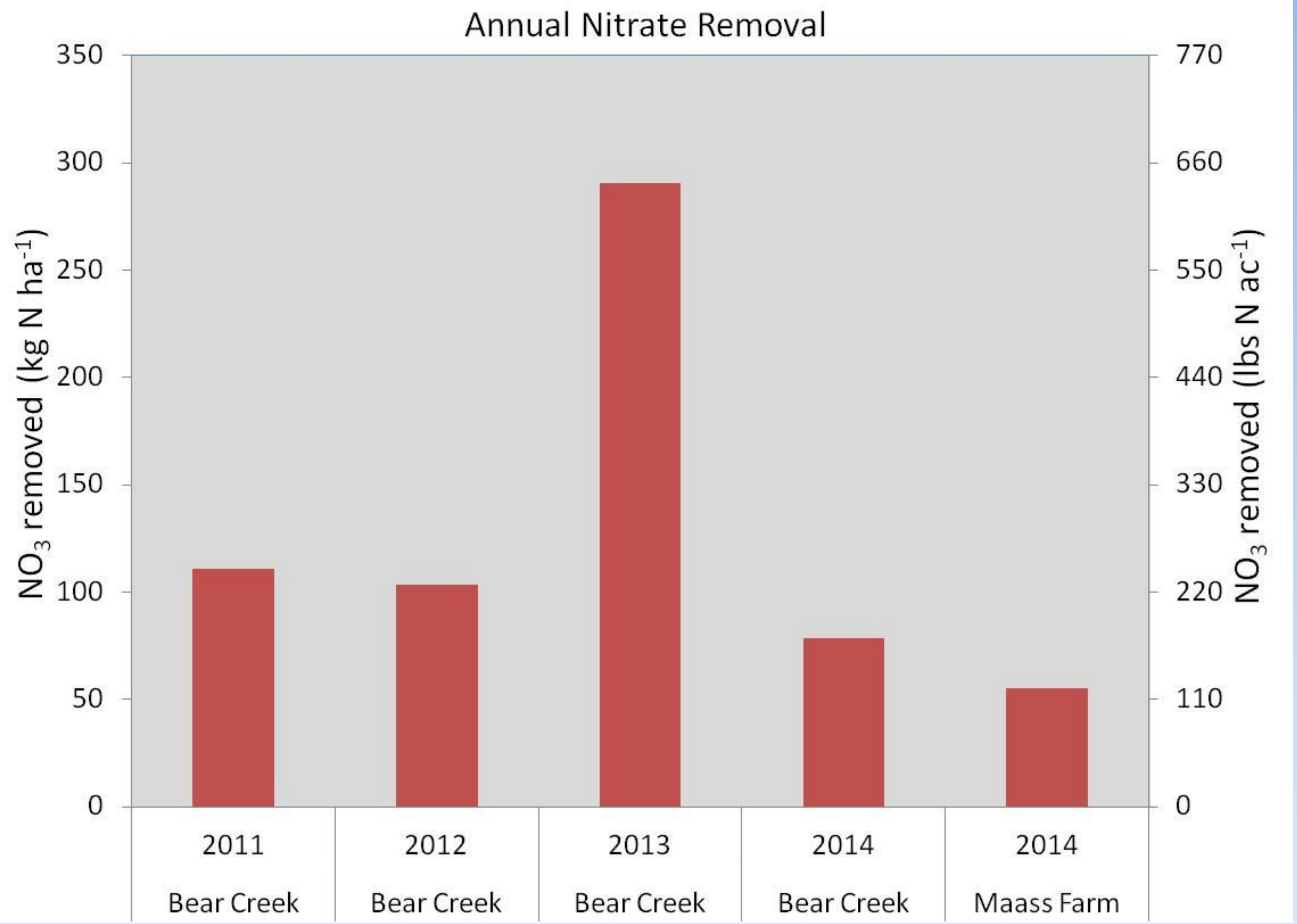



Annual tile flow diverted into buffer or overflow to stream
overflow
diverted
flow (mm)
flow (in)
500
450
400
350
300
250
200
150
100
50
0
20
18
16
14
12
10
8
6
4
2
0
56%
59%
35%
25%
58%
2011
Bear Creek
2012
Bear Creek
2013
Bear Creek
2014
Bear Creek
2014
Maass Farm

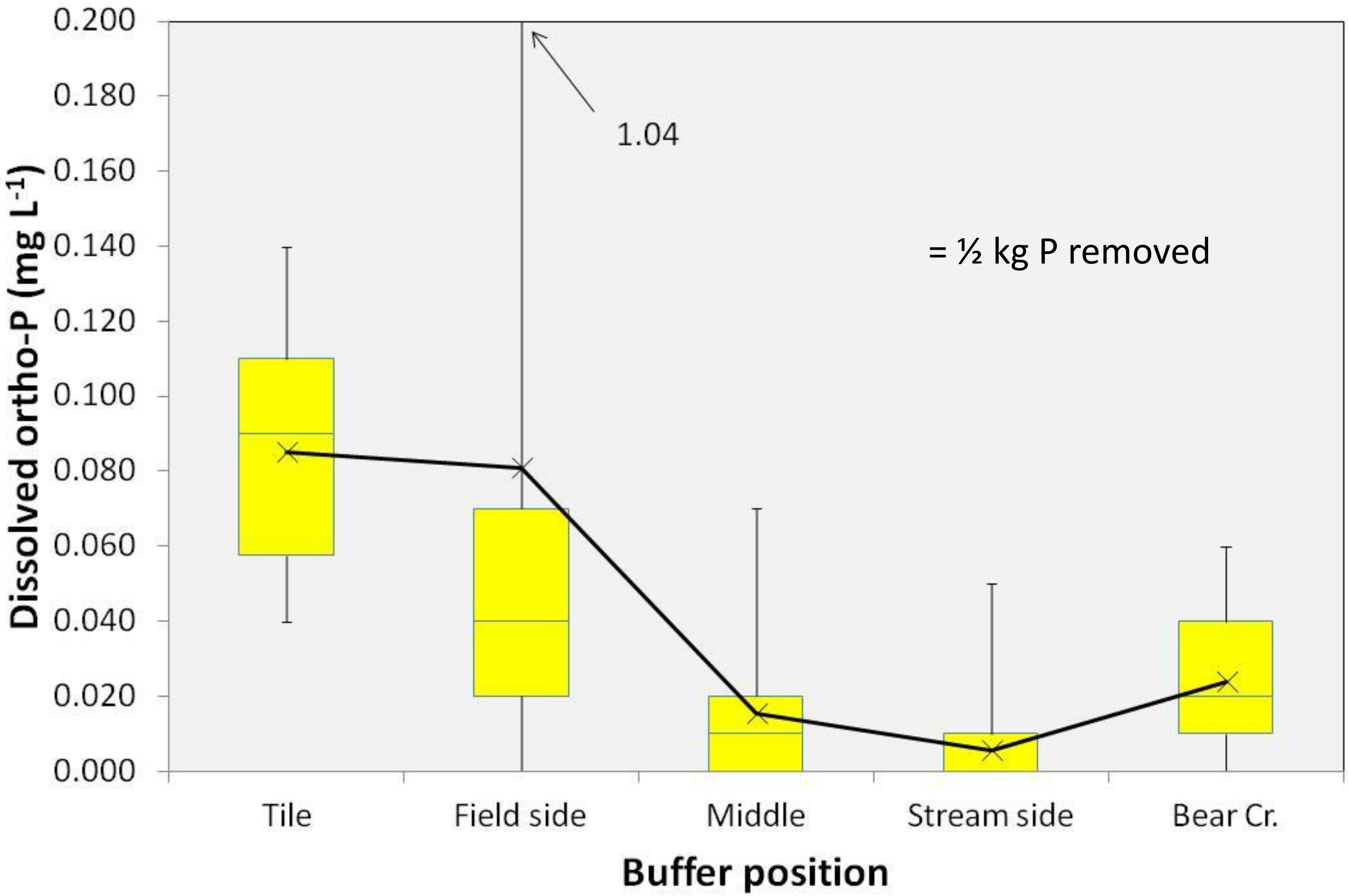
Fate of Nitrate in Buffer
Well Data

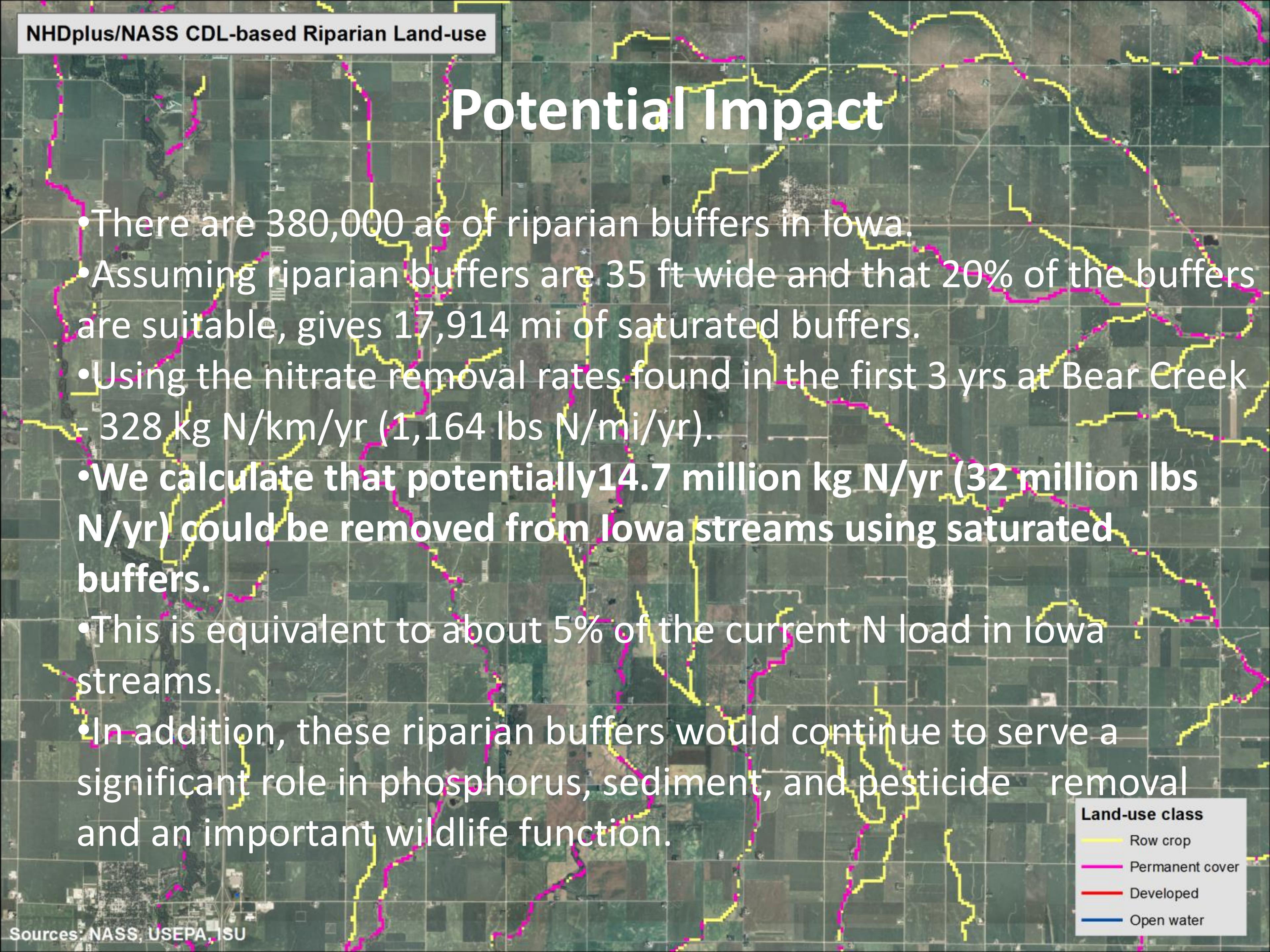
Transect #	Well #	Distance from tile (m)	27-Mar	2-Apr	10-Apr	16-Apr	23-Apr	7-May	14-May	21-May	4-Jun
			Date - 2012								
			---------- NO_3 (mg N L^{-1}) ----------								
1	01	5.7	3.8	6.9	4.6	6.1	8.4	9.7	8.4	9.8	10.6
1	02	12.7	< 0.3	< 0.3	0.8	0.9	0.5	0.5	2.4	3.1	4.7
1	03	18.9	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
2	04	5.7	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
2	05	[illegible]	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
2	06	21.4	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
3	07	6.6	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	2.7
3	08	14.1	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
3	09	22.9	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
4	10	6.0	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	0.6	0.6	0.5	2.4
4	11	14.1	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
4	12	22.2	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
Field			14.1	13.2	13.4	15.1	14.9	15.9	14.7	16.3	15.8
Bear Creek			7.3	4.8	5.5	12.6	12.7	11.0	12.6	12.7	11.5

100% nitrate removal


Annual Nitrate Removal
NO_3 removed (kg N ha^{-1})
NO_3 removed (lbs N ac^{-1})
350
300
250
200
150
100
50
0
770
660
550
440
330
220
110
0
2011
Bear Creek
2012
Bear Creek
2013
Bear Creek
2014
Bear Creek
2014
Maass Farm

P removal in 2012





Potential Impact

- There are 380,000 ac of riparian buffers in Iowa.
- Assuming riparian buffers are 35 ft wide and that 20% of the buffers are suitable, gives 17,914 mi of saturated buffers.
- Using the nitrate removal rates found in the first 3 yrs at Bear Creek - 328 kg N/km/yr (1,164 lbs N/mi/yr).
- **We calculate that potentially14.7 million kg N/yr (32 million lbs N/yr) could be removed from Iowa streams using saturated buffers.**
- This is equivalent to about 5% of the current N load in Iowa streams.
- In addition, these riparian buffers would continue to serve a significant role in phosphorus, sediment, and pesticide removal and an important wildlife function.

Economics

- For Bear Creek, we installed 1,100 ft of 4 in. tile at a cost of $2,508 @ $2.28 per foot installed. The control box was $1,120 installed. Another $100 would typically be required for design work for the system.
- Assuming a 20-yr life expectancy for the system at 4% interest would add about $1,460. Thus, the total cost of the installation will be $5,188 over 20 yr or $259 per year.
- We removed an average of 168 kg (371 lbs) of nitrate-N over the first three years at Bear Creek.
- **Thus, the annual cost per kg N removed for this prototype system was $1.54/kg ($0.70/lbs) nitrate-N removed.**
- This cost is very competitive with estimates for other nitrate removal practices such as constructed wetlands ($2.91/kg) and fall planted cover crops ($6.77/kg).

Summary

- First 3 years show that diverting tile flow into riparian buffers can remove all the nitrate that is diverted into them
- We diverted 55% of the flow from a field tile draining ~25 ac
- The cost of the practice is comparable to other N removal practices
- Practice shows potential of preventing > 18 million lbs of N from entering IA streams each year
- New Interim Conservation Practice Standard

NATURAL RESOURCES CONSERVATION SERVICE
INTERIM CONSERVATION PRACTICE STANDARD

VEGETATED SUBSURFACE DRAIN OUTLET

(Ft.)

CODE 739

DEFINITION

A water control structure and subsurface distribution pipe capable of diverting drainage system discharge to create an elevated zone of soil saturation.

PURPOSE

The structural measures installed shall be used to achieve one or more of the following purposes:

- To reduce nitrate loading from subsurface drain outlets
- To enhance or restore saturated soil conditions in riverine, lacustrine fringe, slope, or depression hydrogeomorphic (HGM) landscape classes

CONDITIONS WHERE PRACTICE APPLIES

This practice is applicable to agricultural lands with subsurface agricultural drainage systems that can be adapted to allow management of drainage discharges.

This practice can be applied where the soils and topography are capable of maintaining a raised water table without adverse effects to channel banks, shorelines, or adjacent land.

This practice shall not be used to treat septic system discharge or animal waste.

CRITERIA

General Criteria Applicable to All Purposes

Geologic and soil investigations shall be conducted to confirm:

- conditions such as a restrictive layer or high water table are present to maintain an elevated water table with water diverted from the subsurface drainage system
- the absence of pockets of high conductivity soil which could provide preferential flow paths

The soil saturation area shall be vegetated to prevent erosion and to utilize nitrogen from the drain water. The minimum width of the vegetated zone for this practice shall be 30 feet.

Design water control structures (diverter box) in accordance with NRCS Conservation Practice Standard Structure for Water Control (587). The water control structure shall be accessible for water table observation and for operation and maintenance.

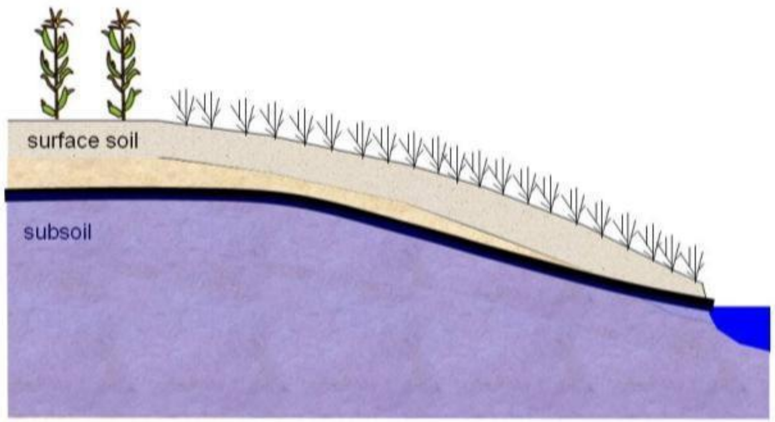
Design the water control structure to maintain the design water table elevation over the distribution pipe during the management period, based on expected flow rates from the subsurface drainage system.

Design the distribution pipe and overflow pipe in accordance with NRCS Conservation Practice Standard Subsurface Drain (606). The overflow pipe shall be non-perforated for a distance sufficient to avoid draining the saturated soil zone around the water control structure.

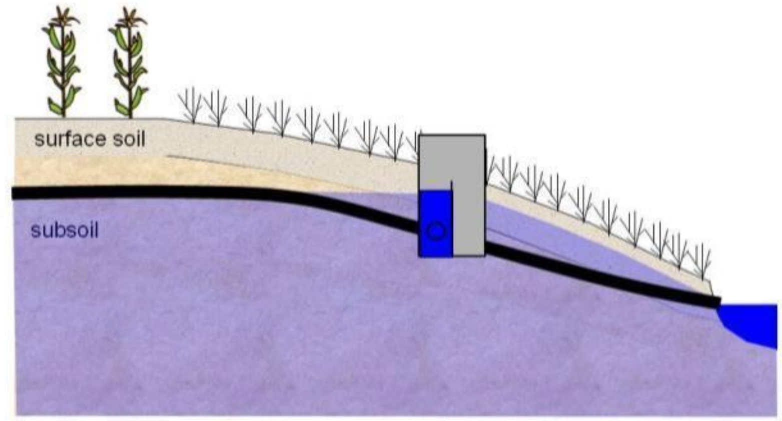
Locate and design the system to maximize the amount of subsurface drainage water diverted to the saturated soil zone. Ensure there are no adverse impacts to adjacent lands.

Design Considerations

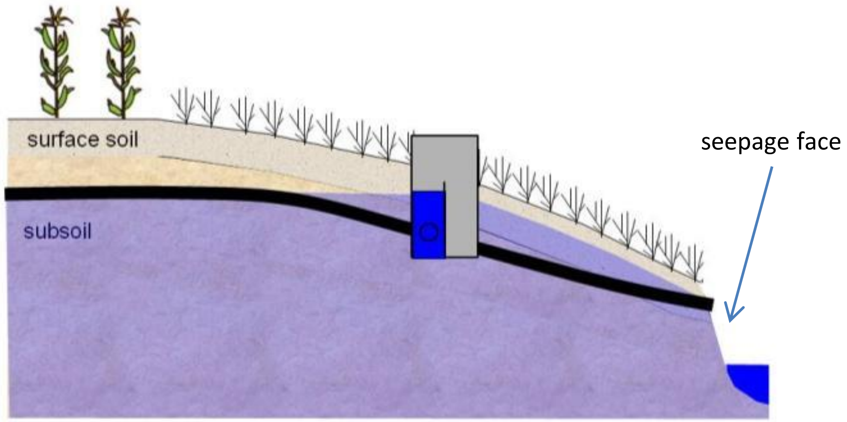
Siting Saturated Buffers



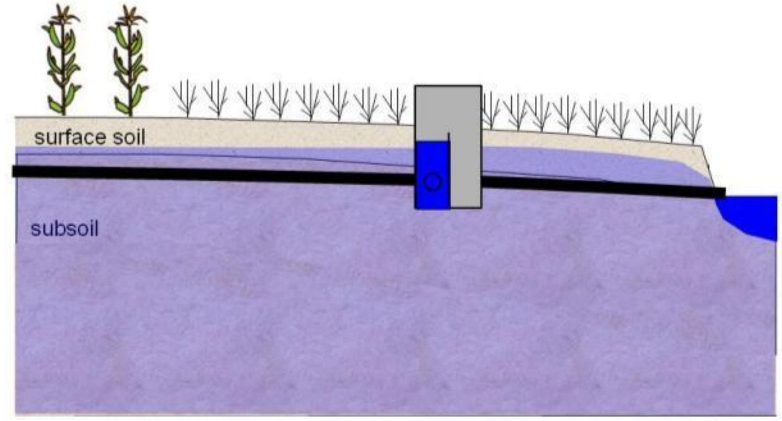
Ideal riparian buffer



Saturated Buffer



Deeply incised channel



Flat landscape

Soil Considerations

To support denitrification:

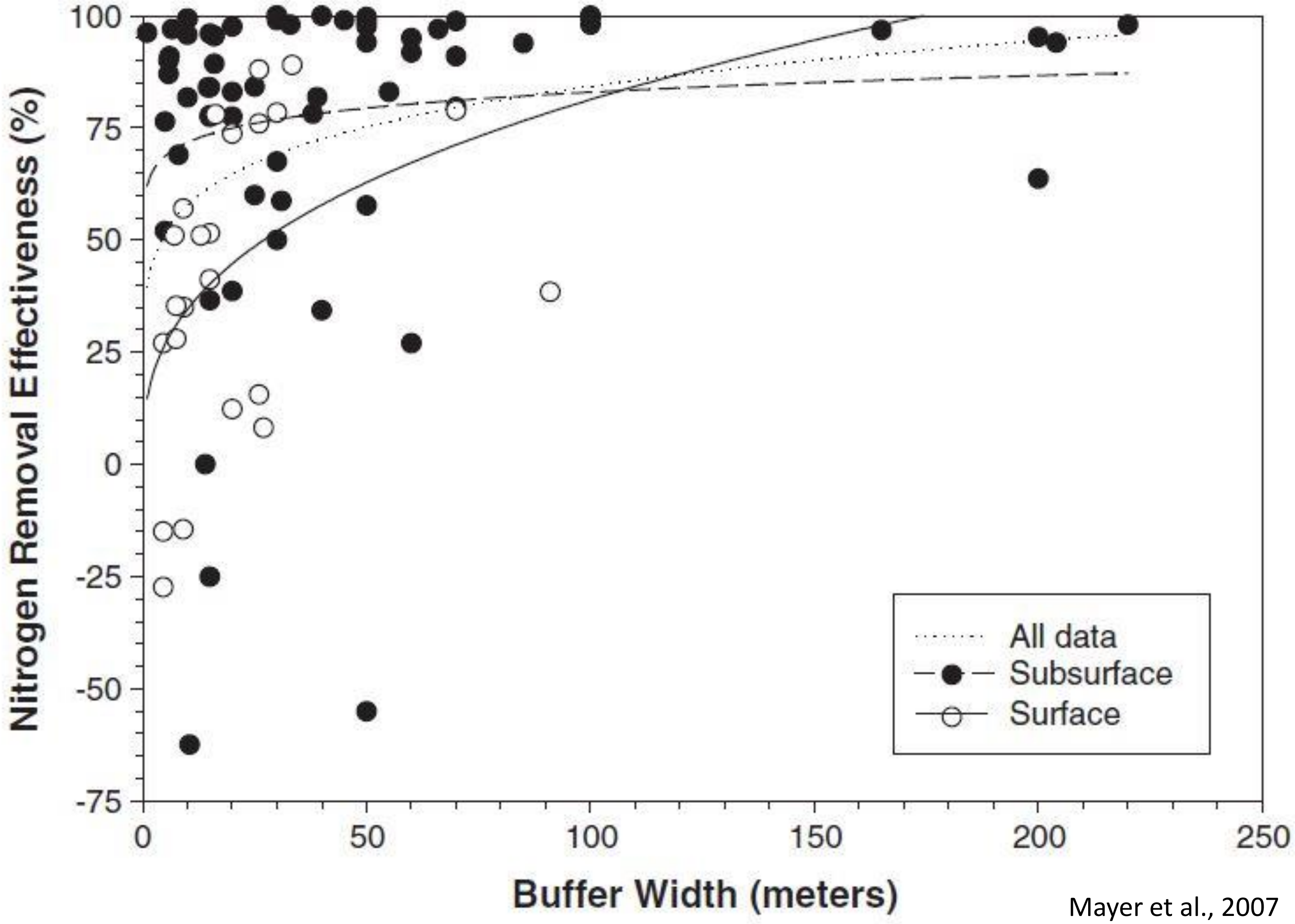
- Soil needs to be high in organic carbon

Soil Considerations

To support denitrification:

- Soil should not be too permeable (sands – gravels) nor impermeable (heavy clays)

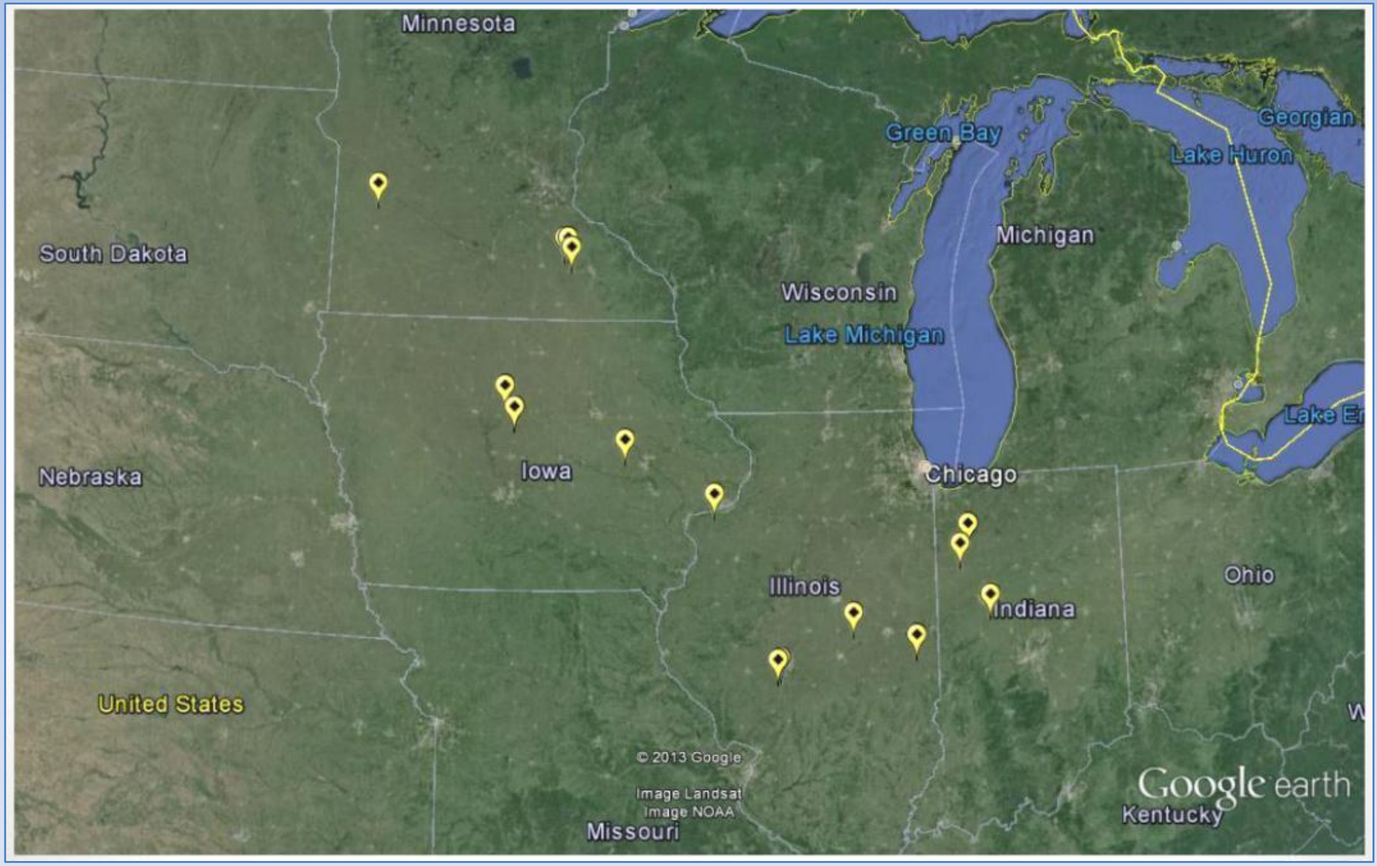
Buffer Width (biological limitation)



Mayer et al., 2007

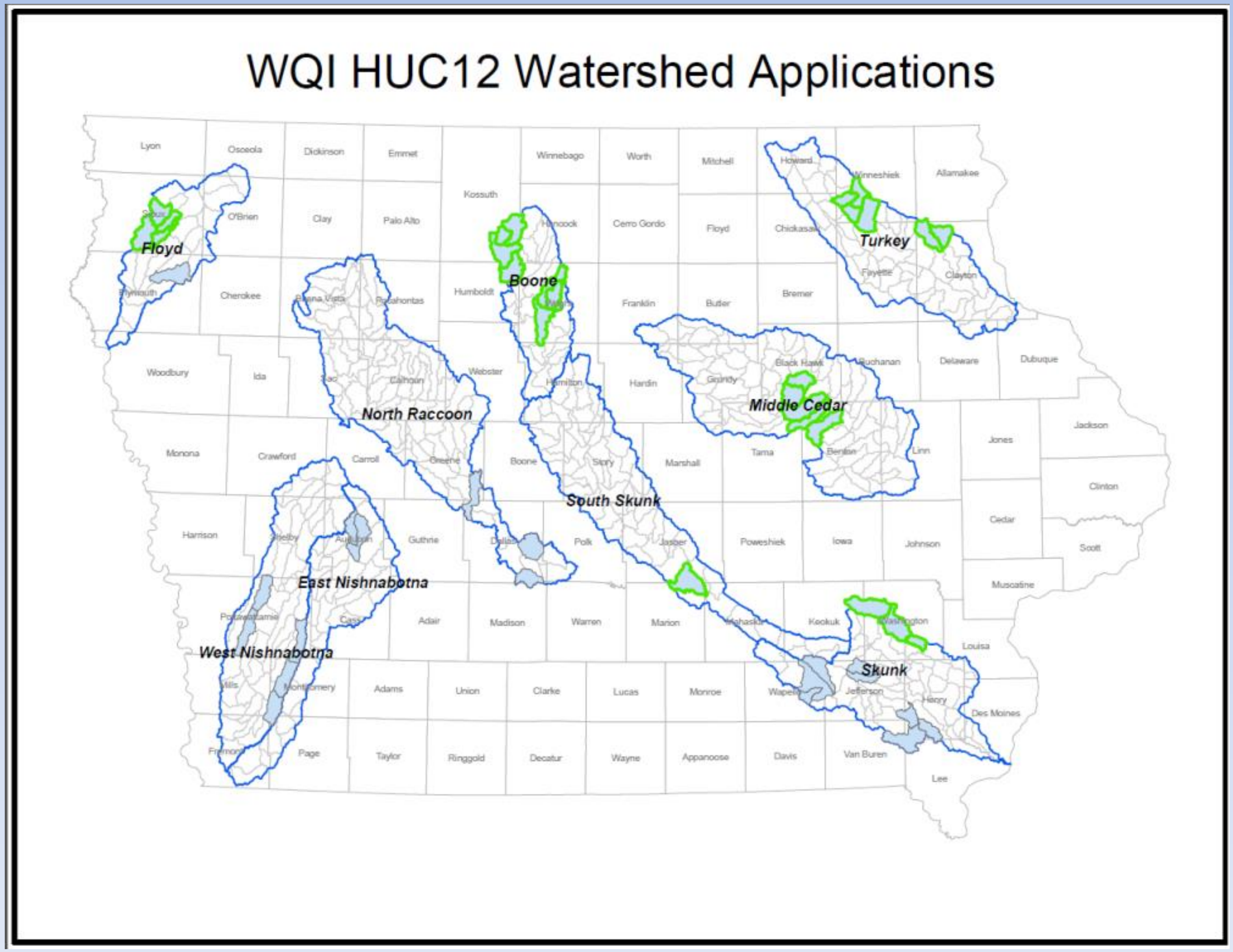
Phase II

Expanding study by installing saturated buffers at 15 new sites in MN, IA, IL, and IN (FSA & NRCS CIG – Agricultural Drainage Management Coalition)



Phase III

Watershed demonstration projects focusing on adoption of practices outlined in the Iowa Nutrient Reduction Strategy



Thank you

Dan Jaynes
515-294-8243
dan.jaynes@ars.usda.gov
http://www.ars.usda.gov/pandp/people/people.htm?personid=2789